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Effect of Substituting Fishmeal with Oilseed Meals on Diets Fatty Acid and Proximate Composition for Nile tilapia (*Oreochromis niloticus*)

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Abstract
The study aimed to evaluate the fatty acid and proximate composition of diets for Nile tilapia containing soybean meal (SBM), canola meal (CM) and sunflower meal (SFM) as replacements of fishmeal (FM). A control diet (D1) of 30% crude protein (CP) was formulated using fishmeal as main protein source. The test diets (D2, D3 and D4) were formulated by replacing 10% CP of FM by SBM, CM and SFM, respectively. The fatty acid profile of ingredients and diets were determined by MPA FT-NIR spectrometer. FM displayed higher CP content (62.60%) followed by SBM (47.38%), CM (34.39%) and SFM (24.81%). SFM had highest crude fibre content ($p<0.05$) while CM displayed higher figure for ether extracts ($p<0.05$). Substituting FM with SBM, CM and SFM increased the levels of crude fibre ($p<0.05$). Diet 4 recorded highest crude fibre (16.03%) content ($p<0.05$), while CM based diet recorded highest ether extract content (10.75%), ($p<0.05$). Diet 1 had lowest concentration (21.85mg/100g) of total saturated fatty acid and D2 lowest concentration of polyunsaturated fatty acid (29.90mg/100g). The study revealed that 10% CP substitution of FM with SBM, CM and SFM in Nile tilapia diets is possible without much negative change in diets proximate and fatty acid composition.
Key words: *Crude protein, Essential fatty acids, Nile tilapia, Nutrients composition*

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I. Introduction

A major problem faced by the aquaculture industry is the cost of nutrition, of which protein (specifically fishmeal) is the most expensive ingredient (Webster and Chhorn, 2006). Protein is an indispensable nutrient that must be incorporated in the fish diet at sufficient proportion to guarantee sufficient growth and health of fish (Ogunji *et al.*, 2008). Fish meal is considered the most desirable animal protein ingredient in aqua feeds because of its high protein content, balanced amino acid profile, high digestibility and palatability, and as a source of essential n-3 polyenoic fatty acids (Hardy and Tacon, 2002). However, the high costs and scarcity in Kenya is the major limitation to its use. Based on this, alternative cheap ingredient in the diets of aquaculture species is a necessity in order for aquaculture to fulfill its role of providing proteins for humans (Bunda *et al.*, 2015). Plant feedstuffs have been used to replace FM due to their more constant availability, and lower costs, despite presenting lower protein content, amino acid imbalances, antinutritional factors , digestibility and palatability than FM (Gatlin *et al.*, 2007; Hardy, 2010). However, blending of different protein ingredients to partially substitute fish meal can lower feed costs without much alteration on proximate nutrient composition.

Among the plant protein feedstuffs, oilseed meals (soybean meal, canola meal and sunflower meal) offer the best substitute for fishmeal due to their relatively high crude protein content, availability and low cost. Soybean meal is a by-product after removal of oil from soybeans and it is the major plant protein source used in aquaculture feeds, not only because of its high protein content but also due to its worldwide availability (Hertrampf and Piedad-Pascual, 2000). Canola meal results from the solvent extraction of canola oil and it is readily available worldwide. The whole seed contains approximately 21% crude protein while canola meal contains approximately 36% crude protein (Naczk *et al.*, 1998). Sunflower meal is a potential substitute for fish meal with a crude protein 30% but ranges from 25 to 45% (air-dry basis) depending on the extent of dehulling and the efficiency of the oil extraction process (Maina *et al.*, 2007). According to Bunda *et al.*, (2015), proximate analysis is used in the initial evaluation of feeds and feedstuffs to provide information on their major nutrient and gross energy contents. However, although the protein component in fish feed has always been a major concern both for the fish feed manufacturers and fish farmers, fish like all other vertebrates require essential fatty acids (EFA) for normal growth, development and reproduction (Sargent *et al.,* 1999; Tocher 2010). According to Ariful Alam *et al.,* (2014), recent study and publication about farmed tilapia omega 3 and 6 fatty acid balance in fillet depending on feed provided and concern about human health hazard deserves some attention and justification. Essential fatty acids are unsaturated fatty acids that must be provided preformed in the diet (NRC, 1993). The objective of this study therefore was to evaluate the proximate and fatty acid composition of Nile tilapia diets on substituting fish meal with oilseed meals (soybean meal, canola meal and sunflower meal).

II. Material and Methods

Preparation of diets

The experiment was conducted at Chuka University, animal nutrition laboratory. A control diet (D1) of 30% CP was formulated in triplicate using fishmeal (*Rastrionaebola argentea*), soybean meal, canola meal, sunflower cake, maize meal, wheatbran. The test diets were similarly prepared by replacing 10% of the CP supplied by FM by either SBM (D2), CM (D3) or SFM (D4) (Table 1). The ingredients were ground using hammer mill to be uniform before mixing.

Table 1: Ingredient composition (%) and calculated crude protein (%) and digestible energy of diets for Nile tilapia containing either soybean meal (D2), canola meal (D3) or sunflower meal (D4) as a replacement of 10% (on CP basis) of Fishmeal (D1)

Ingredient	D1	D2	D3	D4
Fish meal	16.50	9	9	9
Soybean meal	13	24	15	16
Canola meal	16.50	16	31	15
Sunflower cake	18	19	18	43
Maize meal	18	16	13	10
Wheat bran	18	16	14	7
Total	100	100	100	100
Calculated crude protein (%)	30.20	30.10	30.20	30.10
Calculated digestible energy (Kcal/kg)	2997.08	2965.08	2949.63	2878.11

Diet code: D1, fishmeal based diet; D2, soybean meal based diet; D3, canola meal based diet; D4, sunflower meal based diet

Chemical analysis of ingredients and feeds

The proximate analysis of ingredients and diets were carried out as described by the AOAC (1995). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined sequentially by the method of Van Soest *et al.,* (1991). Fatty acid analysis was performed by MPA FT-NIR spectrometer (Bruker, Germany) which is a non-destructive method of analysis (Kirimi *et al.,* 2020).

Data analysis

The proximate and fatty acid composition data of ingredients and diets were subjected to analysis of variance (ANOVA) using SPSS statistical package version 17.0 at P= 0.05 confidence level to determine whether there were significance differences and where the differences occurred, mean separation was done by least significance difference (LSD).

III. Results

Ingredients proximate composition

The proximate nutrient composition of feed ingredients is shown in (Table 2). Fishmeal had highest crude protein content of 62.60% followed by soybean meal (47.38%). Sunflower meal recorded highest figures for crude fibre (36.38%), acid detergent fibre (22.45%) with fishmeal recording the lowest crude fibre content (1.04%). Fish meal had highest level of ash content (15.22%). Canola meal had the highest lipid content (23.88%) and wheat bran lowest lipid content (4.30%). Maize meal recorded lowest figures for crude protein (10.65%), acid detergent fibre (3.52%). However, wheat bran had highest levels of neutral detergent fibre (46.95%).

Table 2: Proximate composition of feed ingredients (%) used to formulate diets for Nile tilapia

Proximate composition	Fish meal	Soybean meal	Canola meal	Sunflower meal	Maize meal	Wheat bran
DM	92.33±0.25[cb]	92.37±0.07[bc]	91.07±0.05[e]	94.42±0.21[a]	88.42±0.11[f]	90.10±0.03[d]
CP	62.60±0.38[a]	47.38±0.32[b]	34.39±0.18[c]	24.81±0.03[d]	10.65±0.27[f]	16.04±0.43[e]
EE	7.49±0.32[d]	9.27±0.30[c]	23.88±0.24[a]	13.31±0.10[b]	4.73±0.23[ef]	4.30±0.17[fe]
Ash	15.22±0.59[a]	8.96±0.26[b]	5.50±0.26[dec]	5.08±0.14[ed]	1.41±0.19[f]	6.17±0.24[cd]
CF	1.04±0.09[f]	15.88±0.32[bc]	15.58±0.20[cb]	36.38±0.20[a]	3.79±0.28[e]	14.41±0.22[d]
NFE	5.92±0.32[f]	10.88±0.26[ed]	11.72±0.32[de]	14.83±0.47[c]	67.85±0.44[a]	49.18±0.75[b]
NDF	34.24±0.20[d]	28.16±0.38[e]	21.07±0.14[f]	43.03±0.30[b]	40.79±0.23[c]	46.95±0.18[a]
ADF	15.22±0.21[b]	9.89±0.22[e]	11.99±0.22[dc]	22.45±0.27[a]	3.52±0.32[f]	12.28±0.19[cd]

Values are expressed as mean ± SE [a,b,c,d,e,f], Values in the same row with different superscript letters show differences ($p<0.05$).
Abbreviations: ADF, acid detergent fibre; DM, dry matter; CF, crude fibre; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; NFE, nitrogen free extracts.

Ingredients fatty acid composition

Results of the diets fatty acid composition is shown in (Table 3). Fish meal recorded highest concentration of fatty acids. Palmitic acid (16:0), stearic acid (18:0) and oleic acid (18:1n-9) were detected in all the ingredients with fishmeal recording the highest concentration. Eicosatrienoic acid (20:3n-3), eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3) were abundant in fishmeal only. α-linolenic acid (C18:3n-3, eicosanoic acid (C20:0), docosanoic acid (C22:0) were only detected in soybean meal.

Table 3: Fatty acid composition (mg/100g) of ingredients used to formulate diets for Nile tilapia

Fatty Acid	Fish meal	Soybean meal	Canola meal	Sunflower meal	Maize meal	Wheat bran
C 14:0	4.67	ND	ND	1.11	ND	ND
C 16:0	21.70	3.09	11.23	15.35	13.02	17.63
C 18:0	9.32	2.35	2.16	5.26	1.98	1.04
C 16:1n-7	8.27	ND	ND	1.66	ND	ND
C18:1n-9	14.97	20.49	33.78	33.73	33.91	38.63
C 22:1n-9	2.81	ND	ND	ND	ND	ND
C 24:1n-9	0.61	ND	ND	ND	ND	ND
C 20:3n-3	0.11	ND	ND	ND	ND	ND
C 20:5n-3	7.09	ND	ND	ND	ND	ND
C 22:6n-3	14.64	ND	ND	ND	ND	ND
C 18:3n-3	ND	5.20	ND	ND	ND	ND
C 20:0	ND	0.59	ND	ND	ND	ND
C 20:1	ND	0.19	ND	ND	ND	ND
C 22:0	ND	0.17	ND	ND	ND	ND
C 18:3	ND	ND	0.66	ND	0.88	2.47

ND: means not detected

Diets proximate composition

Proximate composition of the diets is shown in (Table 4). Crude protein values for D1, D2, D3 and D4 were near isoproteinous (30.57%, 30.76%, 30.34% and 31.35% respectively ($p>0.05$). D3 recorded highest level of ether extracts 10.75% ($p<0.05$) and low for D1 (7.55%). D1 had highest ash content (6.16%) but low in crude fibre content (11.06%) with D4 recording highest crude fibre content (16.03%). However, all the diets recorded almost the same amount of neutral detergent fibre although D4 recorded slightly lower figure (23.08%). Acid detergent fibre were within the same range but D4 recorded highest (11.86%).

Table 4: Proximate composition of the diets (%) for Nile tilapia containing either soybean meal (D2), canola meal (D3) or sunflower meal (D4) as a replacement of 10% (on CP basis) of Fishmeal (D1)

Proximate composition	D1	D2	D3	D4
DM	90.90±0.07[dbc]	91.31±0.16[dbca]	91.10±0.09[dbca]	91.56±0.19[abc]
CP	30.57±0.43[a]	30.76±0.53[a]	30.34±0.31[a]	31.35±0.33[a]
EE	7.55±0.27[cd]	7.67±0.18[cd]	10.75±0.28[a]	9.63±0.18[b]
Ash	6.16±0.03[abc]	5.60±0.24[abc]	5.40±0.21[dbc]	5.81±0.17[abc]
CF	11.06±0.08[d]	12.18±0.12[c]	13.37±0.17[b]	16.03±1.00[a]
NFE	42.45±0.21[ab]	42.79±0.65[ab]	37.44±0.56[cd]	36.09±0.51[cd]
NDF	24.07±0.22[cab]	24.41±0.31[abc]	24.41±0.23[bac]	23.08±0.34[d]
ADF	8.37±0.25[cd]	8.23±0.30[dc]	11.83±0.20[ba]	11.86±0.47[ab]

Values are expressed as mean ± SE [a, b, c, d]. Values in the same row with different superscript letters show differences ($p<0.05$).
Abbreviations: ADF, acid detergent fibre; DM, dry matter; CF, crude fibre; CP, crude protein; EE, ether extract; NDF, neutral detergent fibre; NFE, nitrogen free extracts.

Diets fatty acid composition

The fatty acid composition of the diets is shown in Table 5. Soybean meal based diet (D2) had a high level of palmitic acid (16:0) (15.35mg/100g) compared to the other diets. However, sunflower meal based diet (D4) recorded the highest level of saturated fatty acid (23.51mg/100g). Diet 1 (FM based) recorded highest amount of polyunsaturated fatty acid (32.10mg/100g) followed by sunflower meal based diet (D4) (30.30mg/100g).

Table 5: Fatty acid composition of the diets (mg/100g) for Nile tilapia containing either soybean meal (D2), canola meal (D3) or sunflower meal (D4) as a replacement of 10% (on CP basis) of Fishmeal (D1).

Fatty Acids	D1	D2	D3	D4
Saturated				
C 14:0	$4.14±0.01^{d}$	$4.47±0.01^{b}$	$4.36±0.01^{c}$	$5.11±0.01^{a}$
C 16:0	$15.05±0.01^{c}$	$15.35±0.01^{a}$	$14.77±0.01^{d}$	$15.16±0.00^{b}$
C 18:0	$2.98±0.01^{c}$	$2.12±0.01^{d}$	$3.22±0.01^{b}$	$3.26±0.01^{a}$
ΣSFA	$21.85±0.36^{dcb}$	$22.00±0.10^{cdb}$	$22.44±0.07^{bcd}$	$23.51±0.19^{a}$
Mono-unsaturated				
C 16: n-7	$5.36±0.01^{ba}$	$5.17±0.01^{c}$	$4.81±0.01^{d}$	$5.37±0.01^{ab}$
C 18: n-9	$12.75±0.01^{d}$	$13.50±0.01^{b}$	$13.13±0.01^{c}$	$13.73±0.01^{a}$
C 20: n-9	$2.50±0.01^{d}$	$2.71±0.01^{b}$	$2.66±0.01^{c}$	$2.82±0.01^{a}$
C 22: n-9	$4.54±0.01^{c}$	$6.12±0.01^{b}$	$6.90±0.01^{a}$	$5.36±0.01^{d}$
C 24: n-9	$0.81±0.01^{b}$	$0.86±0.01^{a}$	$0.32±0.01^{d}$	$0.49±0.01^{c}$
ΣMUFA	$25.90±0.01^{c}$	$28.30±0.01^{a}$	$27.80±0.00^{b}$	$27.80±0.00^{b}$
Polyunsaturated				
C 18: 2n-6	$15.64±0.01^{a}$	$14.71±0.01^{c}$	$15.23±0.01^{b}$	$12.24±0.01^{d}$
C 18:3n-6	$0.17±0.00^{ab}$	$0.11±0.00^{d}$	$0.13±0.00^{c}$	$0.15±0.00^{ba}$
C 20:4n-6	$0.62±0.01^{ab}$	$0.53±0.01^{cd}$	$0.52±0.01^{dc}$	$0.61±0.01^{ba}$
C 20:3n-3	$0.10±0.01^{a}$	$0.10±0.01^{a}$	$0.11±0.01^{a}$	$0.10±0.01^{a}$
C 20:5n-3	$6.89±0.01^{b}$	$6.33±0.01^{c}$	$7.14±0.01^{a}$	$5.93±0.01^{d}$
C 22:6n-3	$8.64±0.01^{d}$	$7.64±0.01^{a}$	$7.02±0.01^{c}$	$6.87±0.01^{d}$
ΣPUFA	$32.10±0.00^{a}$	$29.90±0.00^{d}$	$30.20±0.00^{c}$	$30.30±0.01^{b}$

Values are expressed as mean ± SE [a, b, c, d]. Values in the same row with different superscript letters show differences ($p<0.05$).
Diet code: D1, fishmeal based diet; D2, soybean meal based diet; D3, canola meal based diet; D4, sunflower meal based diet;
Abbreviations: SFA: Saturated Fatty Acids; MUFA: Monounsaturated Fatty Acids; PUFA: Polyunsaturated Fatty Acids.

IV. Discussion

Proximate nutrient composition of the ingredients

Generally, the proximate composition of the ingredients in this study was within the values obtained by Oduho *et al.,* (2005); Kirimi *et al.,* (2016) and Maina *et al.,* (2007). However, the differences in nutrient composition of feed ingredients could be attributed to the place of origin, production, processing methods and even adulteration by unscrupulous traders (Anjum *et al.,* 2012; Munguti *et al.,* 2021). The ingredients fishmeal, soybean meal, canola meal and sun flower meal had protein contents of 62.60%, 47.38%, 34.39% and 24.81% respectively; these values characterize them as protein feedstuffs (Tacon and Barg, 1999; Lovell, 1998). The crude protein (62.60%) of fishmeal (*Rastrionaebola argentea)* recorded in this study was within the range of values obtained by Kirimi *et al.,* (2016) (64.20%) but higher than that obtained by Maina *et al.,* (2007) who reported a CP of 55%. Fish meal processed from whole fish is of high protein quality, above 60% (Prado *et al.,* 2016). This could have been attributed to the high crude protein content of fish meal in this study. According to Drew *et al.,* (2007) and Anjum *et al.,* (2012), the crude protein content of fish meal range from 50% to 70% depending on fish species, the source and processing method. Ash content was (15.22%); a figure close to 16.13%, obtained by Kirimi *et al.,* (2016) but above that obtained by Oduho *et al.,* (2005). Contamination with sand and organic matter from the drying surfaces may cause the differences in ash and crude fiber contents. Fish meal obtained from fish leftovers has high ash content (Millamena, 2002), which is a limitation when included at high levels in feed as it raises the phosphorus. Ether extract for fish meal was 7.49%, a figure above that recorded by Kirimi *et al.,* (2016) (5.07%) but below that of Oduho *et al.,* (2005). The difference in ether extract is possibly due to age or seasonal variation. According to Okot (1995), pelagic fishes like

Rastrionaebola argentea have two oil cycles, the first beginning December-January (low oil content) which rises to a peak in May-June.

The crude protein (47.38%) of soybean meal was within the range reported by NRC (1993). The variation in protein content in soybean meal is mostly due to method of oil extraction. According to Li *et al.,* (2000), expeller process of oil extraction from soybeans results in a meal containing approximately (42% crude protein), solvent-extraction (44% crude protein) if hulls are included or 48% crude protein without the hulls (NRC 1993). However, full-fat soybean meal produced by heat treating whole soybean contain approximately 38% crude protein (Lim and Akiyama, 1992). Despite the high CP in soybean meal recorded in this study, research by Kirimi *et al.,* (2016) recorded 11% CP which was attributed to adulteration by unscrupulous dealers.

Canola meal had a protein content of (34.39%), (Table 2). The low CP content of canola meal in this study may be attributed by inadequate oil extraction (23.9%). According to Bell and Keith (1991), the proximate composition of canola meal may vary due to cultivars, environment conditions during growing and harvesting periods and crushing conditions. Dry season conditions create lower oil content and higher level of protein content (Spragg and mailer, 2007).

Sunflower meal had a protein content of (24.81%) which is lower than 28% CP reported by Maina *et al.,* (2007). This may be due to the high crude fibre content (36.38%). The crude protein content of ingredient is inversely proportional to the fibre content. The chemical composition of sunflower seed depends on the weather, soil, variety and method of cultivation of the crop (Karunajeewa *et al.*, 1989; Senkoylu and Dale, 1999). The fat content was 13.31%. The difference in values for the crude fat may be due to type of processing method used before ether extraction (Akande, 2011). The crude fibre reported in sunflower was (36.38%) and varies between 14% and 39% (Villamide and San, 1998).

The crude protein content of maize meal was (10.65%). However, nutritive value of maize protein varies according to cultivar, type of grain (dent, flint, dent/flint), growing conditions (Korniewicz *et al.*, 2000), grain drying temperature (Kaczmarek *et al.*, 2007), starch structure (Svihus *et al.*, 2005), and presence of ant nutrients, primarily, phytate, enzyme inhibitors, and resistant starch (Cowieson, 2005).

Proximate nutrient composition of the diets

The crude protein content of the four diets in the present study was near isoproteinous (Table 4). This was attributed to the initial analysis of ingredients prior to formulation of diets inorder to balance for the CP. Dietary protein plays a significant role in supplying amino acids for the biosynthesis of the body proteins which are essential for the growth of fish (Alam *et al.,* 2016; Kirimi *et al.,* 2020). Though the protein content in the four diets was isoproteinous ($p>0.05$), the proportion of protein ingredients (fish meal, soybean meal, canola meal and sunflower meal) varied because of differences in CP. This was in attempt to compensate for the varying nutrients among the ingredients. It's worth noting that this variation of major protein ingredients (FM, SBM, CM and SFM) in each diet led to considerable changes in other nutrients (Table 4). However, the diets in the present study meet the protein requirement for Nile tilapia fingerlings weighing 10-30g and 30g to market size which according to Jauncey (1998); Suresh (2003) is 25% to 30% CP. Luquet (1991) reviewed several studies and recommended a protein content of 30-35% as the optimum for tilapia.

The crude fat content of diets observed was a reflection of the crude fat content in the major protein ingredients used (FM, SBM, CM and SFM). Diet 3 recorded highest amount of crude lipid (10.75%). This was attributed to the high levels of canola meal where it formed the bulk of the protein with a lipid content of 23.88%. Conversely, D1 recorded the lowest crude fat content (7.55%) followed closely by D2 (7.67%). In the two diets (D1 and D2), fishmeal and soybean meal formed the bulk of protein with crude fat content of (7.49%) and (9.27%) respectively. According to NRC (1993), dietary lipids are important sources of energy and essential fatty acids (EFA) needed for normal growth and development and assist in the absorption of fat-soluble vitamins. The dietary lipid content was within the levels recommended (5% to 12%) for tilapia (Suresh, 2003)

The crude fibre content varied among the diets ($p<0.05$). This variation in crude fibre was due to varying of ingredients inorder to balance for the crude protein. The high fibre content in D4 (16.03%) could have been attributed by the high fibre content in sunflower meal (36.38%) where it formed the bulk of the protein. This was followed by D3 where canola meal (15.58% crude fibre) formed the bulk of protein. In D1, the low fibre content recorded (11.06%) was due to high fish meal content which had low fibre content (1.04%). Crude fibre in the feed gives it the physical bulkiness, improves binding and moderates the passage of feed through the alimentary canal (Ayuba and Iorkohol, 2012; Obeng *et al.,* 2015). However, monogastric animals including fish are generally unable to digest fibre because they do not secrete cellulase (Bureau *et al.,* 1999). According to De Silva and Anderson (1995), the recommended fibre content in fish feed is 8-12%. Based on this, the fibre content for D1 and D2 were within the range for Nile tilapia diets. However, D3 and D4 were far above the recommended 13.37% and 16.03% respectively. High levels of fibre content reduces the total dry matter, lowers the digestibility of nutrients, slows growth, adds to the faecal waste which affects the water quality and hence fish performance (De Silva and Anderson, 1995; Lovell, 1998).

Cell wall carbohydrates can be quantified by determination of neutral detergent fibre (NDF), which includes cellulose, hemicellulose and lignin as the major components (Van Soest *et al.*, 1991). In the present study, neutral detergent fibre was closely related among the diets though D4 was significantly different ($p<0.05$) with others. Neutral detergent fibre represents the structural fibre, which is only partially digestible, and lignin is the fraction of NDF that is totally indigestible. Likewise, D3 and D4 recorded higher figures for acid detergent fibre (ADF) (11.83% and 11.86%) respectively. Based on the high NDF compared to the low ADF reported in this study, it implies that a higher portion of the crude fibre in the diets would be digested. However, according to Adewole (2016), the detergent methods were originally developed by Van Soest' for forage analysis. When the same neutral detergent fibre method is used for fibre analysis of cereal grains or protein supplements of monogastric animal diets, a significant under estimation of non-starch polysaccharide (NSP) and thus total dietary fibre content occurs. The ash content in this study slightly varied among the diets with D1 recording slightly higher figure (6.16%). This could be attributed to the high fish meal inclusion with 15.22% ash content. However, Fish, unlike most terrestrial animals, can absorb some minerals (inorganic elements) not only from their diets but also from their external aquatic environment (NRC, 1993).

Fatty acid composition of ingredients and diets

According to Watanabe (1982); Sargent *et al.,* (1989), it is important to profile the fatty acid in the diets of Nile tilapia in order to ascertain the presence of essential fatty acids. This is because the fatty acid composition of the dietary lipid has a significant influence on the tissue fatty acid composition of the fish. In the present study (Table 3), fishmeal recorded highest concentration of fatty acids and this is in agreement with Pike (1999) that fish meal provides fat rich in long chain omega-3 fatty acids. In the oilseed meals (soybean meal, canola meal and sunflower meal), eicosapentaenoic acid (20:5n-3) and docosahexaenoic acid (22:6n-3) were not detected. This agrees with Turchini *et al.,* (2011) that none of the vegetable oils contain omega 3 (n-3) long chain polyunsaturated fatty acids such as eicosapentaenoic acid and docosahexaenoic acid, but they are rich in other fatty acids, mainly stearic acid (18:0), linoleic acid (18:2 n-6) and gamma-linolenic acid (18:3 n-6).Diet 4 recorded lower levels of linoleic acid (12.24 mg/100g). Linoleic acid (18:2n-6) and linolenic (18:3n-3) acids, once obtained from the feed, can be further elongated and desaturated to produce highly unsaturated fatty acids (HUFA), such as arachidonic acid (ARA)(20:4n-6), eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) (Sprecher *et al.,* 1995; Sprecher, 2000). However, the extent to which n-3 HUFA are produced by the elongation and desaturation of 18:3n-3 depends on fish species, life stage and fish size, water temperature and feed, including the dietary lipid source of the fish (Tocher *et al.,* 2000; Tocher *et al.,* 2003). Polyunsaturated fatty acid (PUFA) must be provided in the diets. Based on this, the three very long chain polyunsaturated fatty acids i.e docosahexaenoic acid (22:6n-3), eicosapentaenoic acid (20:5n-3) and arachidonic acid (20:4n-6) were detected in the diets. Fishmeal based diet (D1) recorded higher values for total polyunsaturated fatty acid (32.10mg/100g) attributed to the higher quantity of FM in D1. It's worth noting that although most of the fatty acids were not detected in the oilseed meals, they appeared in the diets. This could be due to their presence in minute quantities which could not be detected but upon mixing of the different ingredients, they rose to detectable levels. Also the diets had some amount of fishmeal i.e only 10% of fishmeal was replaced by respective oilseed meal. According to Ariful Alam *et al.,* (2014), research on the fatty acid requirements of Nile tilapia has produced contradictory results. This could be attributed to various factors such as length of experiment, nutritional history of the experimental fish, size of fish, source of dietary lipids and water temperatures. However, considering that fish are not able to synthesize both the omega-3 and omega-6 series of fatty acids and require them in their diets and based on fatty acid requirements determined for other fish species, it is recommended that a provision of both omega-3 and omega-6 polyunsaturated fatty acid should be included in the Nile tilapia feeds (Ariful Alam *et al.,* 2014).

V. Conclusion

All the diets met the crude protein requirement for Nile tilapia. However, crude fibre content increased with substitution of FM with SBM, CM and SFM. Considerable essential fatty acids necessary for the growth of fish were present in the diets by replacing 10% CP of FM.

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References

[1]. Adewole. D. I., Rogiewicz, A., Dyck, B. and Slominski, B. A. (2016). Chemical and nutritive characteristics of canola meal from Canadian processing facilities. *Animal Feed Science and Technology, 222*, 17–30.

[2]. Akande, K .E. (2011). Proximate and amino acid analyses of full-fat sunflower (*Helianthus annuus* l.) seed meal. *Singapore Journal of Scientific Research, 1*, 179-183. http://dx.doi.org/10.3923/sjsres.2011.179.183

[3]. Alam, S. M., Karim, M. H., Chakrabortty, A., Amin, R. and Hassan, S. (2016). Nutritional characterization of the long-whiskered Catfish *Sperata aur*. A commercially important fresh water fish of Bangladesh. *International Journal of Food Science and Nutrition Engineering, 6*(1), 1-8

[4]. Anjum, M. A., Khan, S. H., Sahota, A. W. and Sardar, R. (2012). Assessment of aflatoxin B1 in commercial poultry feed and feed ingredients. *The Journal of Animal and Plant Sciences, 22*, 268-272. http://www.thejaps.org.pk/docs/v-22-2/05.pdf

[5]. AOAC, (1995). Official Methods of Analysis 16thed; Association of Official Analytical Chemists International, Arlington VA, USA

[6]. Ariful Alam, M. D., Moniruzzaman, S. M., Akter, S., Sarker, B. S. and Minar, M. H. (2014). Omega-3 and 6 fatty acid imbalance found in Tilapia feed in various Tilapia farms of south eastern region of Bangladesh. *World Journal of Zoology, 9* (3), 227-234. 10.5829/idosi.wjz.2014.9.3.85105

[7]. Ayuba, V. O. and Iorkohol, E. K. (2012). Proximate composition of some commercial fish feeds sold in Nigeria. *Journal of Fisheries and Aquatic Science, 8*(1), 248-252. https://scialert.net/abstract/?doi=jfas.2013.248.252

[8] Bell, J. M. and Keith, M. O. (1991). A survey of variation in the chemical composition of commercial canola meal produced in western Canadian crushing plants. *Canadian Journal of Animal Science, 71*, 469–480.

[9]. Bunda, M. G., Tumbokon, B. L. and Serrano Jr, A. E. (2015). Composition, chemical score (CS) and essential amino acid index (EAAI) of the Crinkle grass *Rhizoclonium* spp. as ingredient for aqua feeds. Aquaculture, aquarium, conservation and legislation. *International Journal of the Bioflux, 8*(3), 411-420. http://www.bioflux.com.ro/aacl

[10]. Bureau, D. P., Harris, A. M. and Cho, C. Y. (1999). Apparent digestibility of rendered animal protein ingredients for Rainbow trout (*Oncorhynchus mykiss*).*Aquaculture, 180*(3-4), 345-358.

[11]. Cowieson, A. J. (2005). Factors that affect the nutritional value of maize for broilers. *Animal Feed Science and Technology, 119*, 293-305

[12]. De Silva, S. S. and Anderson, T. A. (1995). Fish nutrition in aquaculture. 319 London: Chapman and Hall.

[13]. Drew, M. D, Borgeson, T. L. and Thiessen, D. L. (2007). A review of processing of feed ingredients to enhance diet digestibility in fin fish: Nutrition technologies in animal feed science and technology. *Animal Feed Science Technology, 138*, 118–136.

[14]. El-Sayed, A. M. (2006). Tilapia culture in salt water: Environmental requirements, nutritional implications and economic potentials. Eighth Symposium on Advances in Nutrition Aquaculture. November 15-17, Nuevo Leon, Mexico.

[15]. Gatlin, D. M., Barrows, F. T., Brown, P., Dabrowski, K., Gaylord, T. G., Hardy, R. W., Harman, E., Hu, G., Krogadhi, A., Nelson, R., Overturf, K., Rust. M., Scaley, W., Skonberg, D., Souza, J., Stone, D., Wilson, R. and Wurtel, E. (2007). Expanding the utilization of sustainable plant products in aquafeeds: A review. *Aquaculture Research, 38*, 551-579

[16]. Hardy, R. W. (2010). Utilization of plant proteins in fish diets: Effects of global demand and supplies of fish meal. *Aquaculture Research, 41*, 770-776

[17]. Hardy, R. W. and Tacon, A. G. (2002). Fish meal: Historical uses, production trends and future outlook for sustainable supplies. pp 311-325. In: Stickney R. R and MacVey P (Editors), Responsible Marines Aquaculture, CABI, UK.

[18]. Hertrampf, J. W. and Piedad-Pascual, F. (2000). Handbook on ingredients for aquaculture feeds. The Netherlands: Kluwer Academic Publishers.

[19]. Jauncey, K. (1998). Tilapia feeds and feeding. Stirling, Scotland: Pisces Press Ltd, p. 241.

[20]. Kaczmarek, S., Jozefiak, D., Bochenek, M. and Rutkowski, A. (2007). The effect of drying temperature of maize grain on nutrient digestibility and nitrogen retention by growing broiler chickens. In: Proceedings of XIX International Poultry Symposium PB WPSA, Olsztyn (Poland), pp. 93

[21]. Karunajeewa, H., Tham, S. H. and Abu-Serewa, S. (1989). Sunflower seed meal, sunflower oil and full-fat sunflower seeds, hulls and kernels for laying hens. *Animal Feed Science and Technology*, 26, 45-54.

[22]. Kirimi, J. G, Musalia, L. M. and Munguti, J. M. (2016). Effect of replacing fish meal with blood meal on chemical composition of supplement for Nile tilapia (*Oreochromis niloticus*).*East African Agricultural and Forestry Journal, 82*(1), 1-9.

[23]. Kirimi, J. G., Musalia, L. M., Magana, A. and Munguti, J. M. (2020). Protein quality of rations for Nile Tilapia (*Oreochromis niloticus*) containing oilseed meals. *Journal of Agricultural Science, 12*(2), 82-91. https://doi.org/10.5539/jas.v12n2p82

[24]. Korniewicz, A., Kosmala, I., Czarnik-Matusewicz, H. and Paleczek, B. (2000). Nutrient contents of varied maize crossbreed (in polish). *Annuals of Animal Science*, 27, 289-303

[25]. Li, M. H., Robinson, E. H. and Hardy, R. W. (2000). Protein sources for feeds. In: Stickney R R (Ed.*),* Encyclopedia of Aquaculture, Wiley and Sons, New York, pp. 688-695.

[26]. Lim, C. and Akiyama, D. M. (1992). Full-fat soybean meal utilization by fish. *Asian Fisheries Science, 5*, 181-197.

[27]. Lovell, R. T. (1998). Nutrition and feeding of fish, 2nd edn. Kluwer Academic, Boston, MA/London.

[28]. Luquet, P. (1991). Tilapia *Oreochromis spp*. In: Hand book of Nutrient Requirements of Finfish. R P Wilson (Editor).CRC Press. Boca Raton, Florida, USA. 196p

[29]. Maina, J. G., Beames, R. M., Higgs, D., Mbugua, P. N., Iwama, G. and Kisia, S. M. (2007). The feeding value and protein quality in high-fibre and fibre-reduced sunflower cakes and Kenya's "omena" fishmeal for Tilapia (*Oreochromis niloticus*).*Livestock Research for Rural Development. 19* (11), 8pp. Retrieved July 22, 2021, from http://www.lrrd.org/lrrd19/11/main19164.htm

[30]. Millamena, O. M. (2002). Replacement of fishmeal by animal byproduct meals in a practical diet for grow-out culture of Grouper *Epinepheluscoiodes*. *Aquaculture, Amsterdam,* 204, 75-84.

[31]. Munguti, J. M**.,** Kirimi, J. G., Obiero, K. O., Ogello, E. O., Sabwa, J. A., Kyule, D. N., Liti, D. M. and Musalia, L. M. (2021). Critical aspects of aquafeed value chain in the Kenyan aquaculture sector - A Review. *Sustainable Agriculture Research, 10*(2), 87-97. https://doi.org/10.5539/sar.v10n2p87

[32]. Naczk, M., Amarowicz, R., Sullivan, A. and Shahidi, F. (1998). Current research and developments on polyphenolics of rapeseed/canola: A review. *Food Chemistry, 62*, 489-502

[33]. NRC, (1993). Nutrients requirements of fish. National Academy Press, Washington, DC USA. https://doi.org/10.17226/2115

[34]. Obeng, A. K., Atuna, R. A. and Aihoon, S. (2015). Proximate composition of Housefly (*Musca domestica*) maggot cultured on different substrates as potential feed for Tilapia (*Oreochromis niloticus*). *International Journal of Multidisciplinary Research and Development, 2*(5), 172-175

[35]. Oduho, G. W., Baker, D. H. and Tuitoek, J.K. (2005). Pelagic fish *Rastrineobola argentea* as a protein source for broiler chicken. *Agricultura Tropica Et Subtropica, 38*(2), 2005

[36]. Ogunji, J., Rahat-Ul-Ain., Summan, T. C. and Schulz, W. K. (2008). Growth performance, nutrient utilization of Nile tilapia (*Oreochromis niloticus*) fed housefly maggot meal (Magmeal) diets. *Turkish Journal of Fisheries and Aquatic Sciences, 8*(1), 141-147

[37]. Okot, M. W. (1995). The chemical composition of Haplochromis and *R. argentea* fish meals. Discovery Innovations 7 (2).

[38]. Pike, I. H. (1999). Health benefits from feeding fish oil and fish meal. Technical Bulletin No: 28, IFFOMA, St. Albans, UK, 1999.

[39]. Prado, S. P., Cavalheiro, O. M., Silva, A. J., Cavalheiro, B. T. and Silva, G. V. (2016). Amino acid profile and percent composition of meals and feeds used in Shrimp farming. *Gaia Scientia, 10*(4), 347-360

[40]. Sargent, J. R., Bell, J. G., McEvoy, L., Tocher, D. and Estevez, A. (1999). Recent developments in the essential fatty acid nutrition of fish. *Aquaculture, 177,* 191-199.

[41]. Sargent, J., Henderson, R. J. and Tocher, D. R. (1989). The Lipids. Pp. 153-218 in Fish Nutrition, 2nd ed., J E Halver, ed. New York: Academic Press.

[42]. Senkoylu, N. and Dale, N. (1999). Sunflower meal in poultry diets: A review. *World Poultry Science Journal, 55,* 153-174.

[43]. Spragg, J. C. and Mailer, R. J. (2007). Canola meal value chain quality improvement. A final report for AOF and Pork CRC.2007. http://www.porkcrc.com.au/ Final Report B-103.pdf.

[44]. Sprecher, H. (2000). Metabolism of highly unsaturated n-3 and n-6 fatty acids. *Biochim Biophysica Acta, 1486*, 219-231.

[45]. Sprecher, H., Luthria, D. L., Mohammed, B. S. and Baykousheva, S. P. (1995). Re-evaluation of the pathways for the biosynthesis of polyunsaturated fatty acids. *Journal of Lipid Research, 36,* 2471-2477.

[46]. Suresh, V. (2003). Farming of aquatic animals and plants, In: Lucas, J. S. & Southgate, P. C., (Eds.) Aquaculture: Blackwell Publishing Oxford, UK. pp. 321-345

[47]. Svihus, B., Uhlen, A. K. and Harstad, O. M. (2005). Effect of starch granule structure, associated components and processing on nutritive value of cereal starch: A review. *Animal Feed Science and Technology, 122,* 303-320

[48]. Tacon, A. G. and Barg, U. C. (1999). Responsible aquaculture for the next millennium, pp. 1–26.In: Proceedings of the seminar-workshop on responsible aquaculture development in south east Asia organized by the SEAFDEC Aquaculture Department, 12–14 October 1999,(Garcia L M B Ed.). Iloilo City, Philippines: Southeast Asian Fisheries Development Center, 274 pp.

[49]. Tocher, D. R. (2010). Fatty acid requirements in ontogeny of marine and fresh water fish. *Aquaculture Research, 41,* 717–732.

[50]. Tocher, D. R., Agaba, M., Hastings, N. and Teale, A. J. (2003). Biochemical and molecular studies of the fatty acid desaturation pathway in fish. In: Browman, H I, Skiftesvik A.B. (Eds.). The big fish bang – Proceedings of the 26th Annual larval fish conference, pp. 211-227. Institute of Marine Nutrition, Bergen

[51]. Tocher, D. R. and Dick, J. R. (2000). Essential fatty acid deficiency in freshwater fish: the effects of linoleic, α- linolenic, γ-linolenic and stearidonic acids on the metabolism of (1-14C) 18:3n-3 in a carp cell culture model. *Fish Physiology and Biochemistry,* 22, 67-75.

[52]. Turchini, G. M., Ng, W. K. and Tocher, D. R. (2011). Fish oil replacement and alternative lipid sources in aquaculture feeds. Taylor & Francis, CRC Press; Boca Raton, FL, USA: 2011. p. 533

[53]. Van Soest, P. J., Robertson, J. B. and Lewis, B. A. (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. *Journal of Dairy Science, 74,* 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

[54]. Villamide, M. J. and San Juan, L. D. (1998). Effect of chemical composition of sunflower seed meal on its true metabolizable energy and amino acid digestibility. *Poultry Science*, 77, 1884-1892. https://doi.org/10.1093/ps/77.12.1884

[55]. Watanabe, T. (1982). Lipid nutrition in fish. Comp. Biochemistry and Physiology, *73*, 3-15.

[56]. Webster, C. D and Chhorn, L. (2006). Tilapia: Biology, culture and nutrition. CRC Press.

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